Guidance for the Presentation of NEXRAD Looping on Cockpit Weather Information Displays

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Outline

- Weather Trending & Animation (Looping)
- Challenges of In-Flight Looping Use
- Looping Design Options, Experiment Issues
- Looping Experiments
  - Experiments 1 and 2: results & status
  - Guidance to date
- Future experiments and opportunities

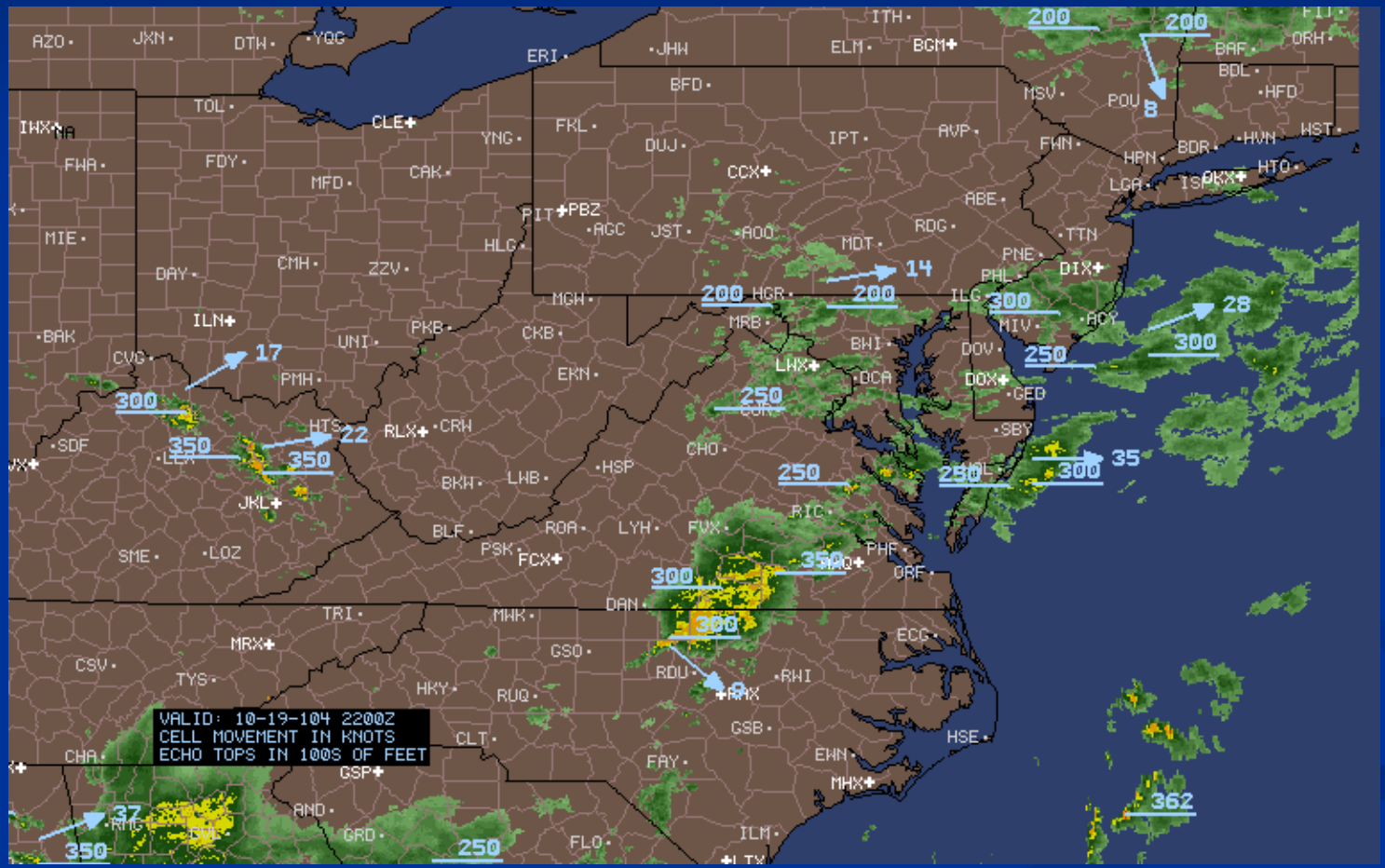
Weather Radar Mosaic Products

- Static NEXRAD Radar Mosaic Images
  - Depicts spatial nature of weather
  - Temporal changes (trends) not depicted
  - Pilot must build/visualize trend information over time

- Depicting Weather Trends
  - Static trend symbols, derived from…
    - Recent history (e.g., Radar Summary)
    - Near-term forecast (e.g., National Convective Weather Forecast - NCWF)
  - NEXRAD image animation (“Weather Looping”)

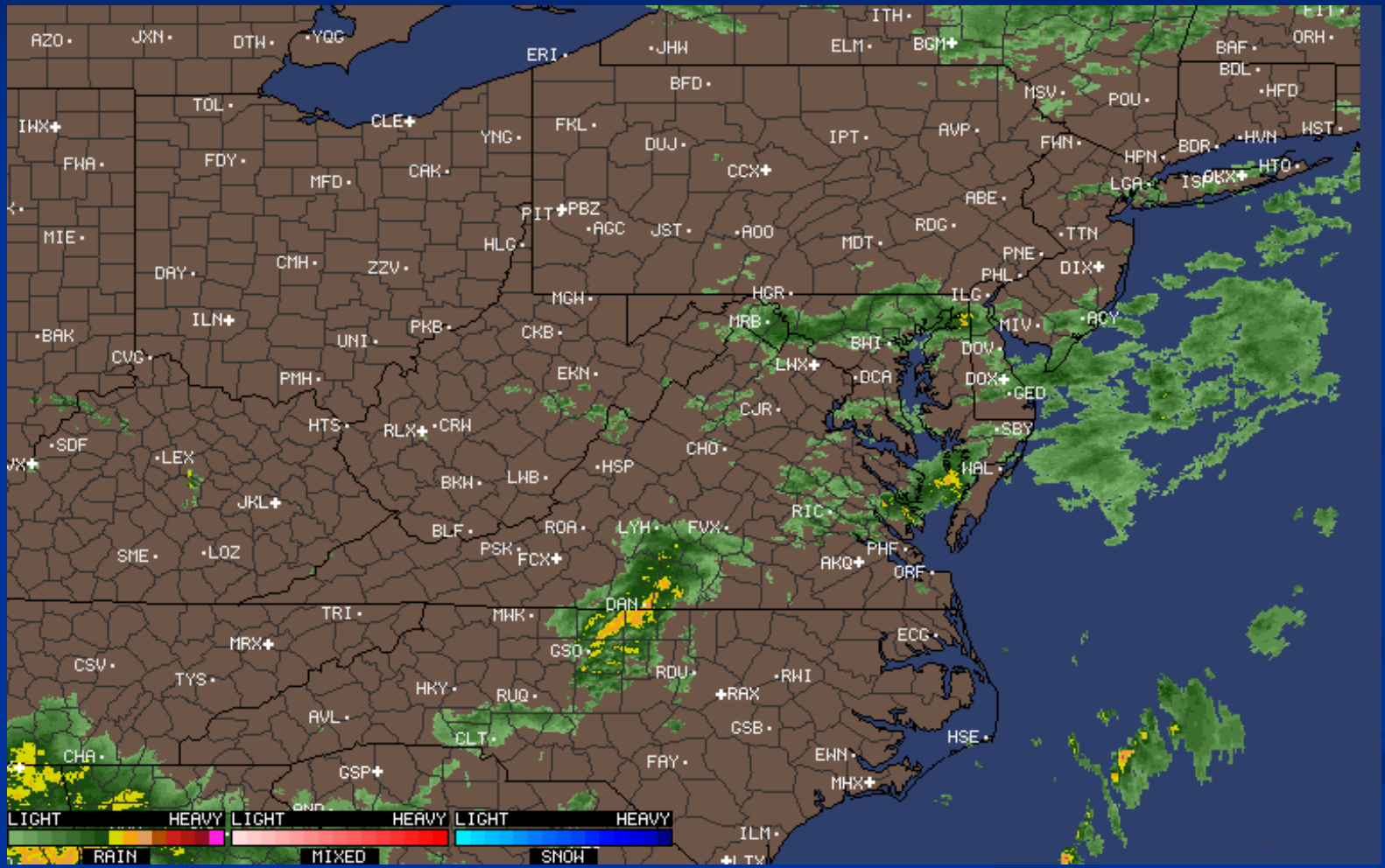
Static NEXRAD Mosaic Image

Static Trend Symbols (Radar Summary)



Near-Term Forecasts (NCWF)

NEXRAD Looping



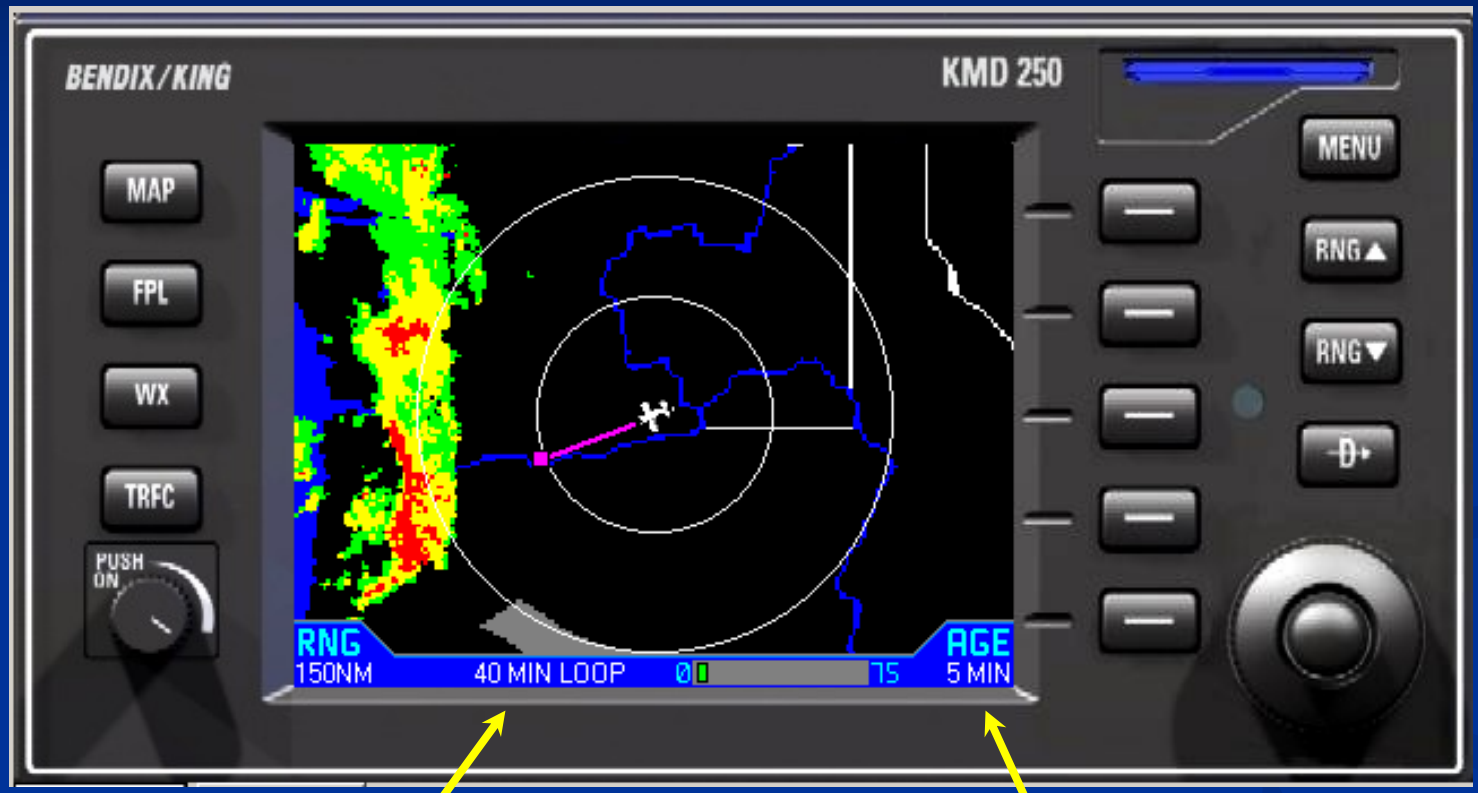
Weather Looping: Challenges of Airborne Use

- Limited Glance Time
- Moving Reference Frame
- Shorter Planning Horizon
- Limited Data-Link Capacity and Avionics Performance

Airborne Looping: Limited Glance Time

- Consider Faster Loop Animation Cycles
  - May work better with instrument scans
  - How fast is too fast?
- Simplify Display Symbols & Motion
  - Don’t animate everything
  - Example: Weather looping product age

Loop Age Example



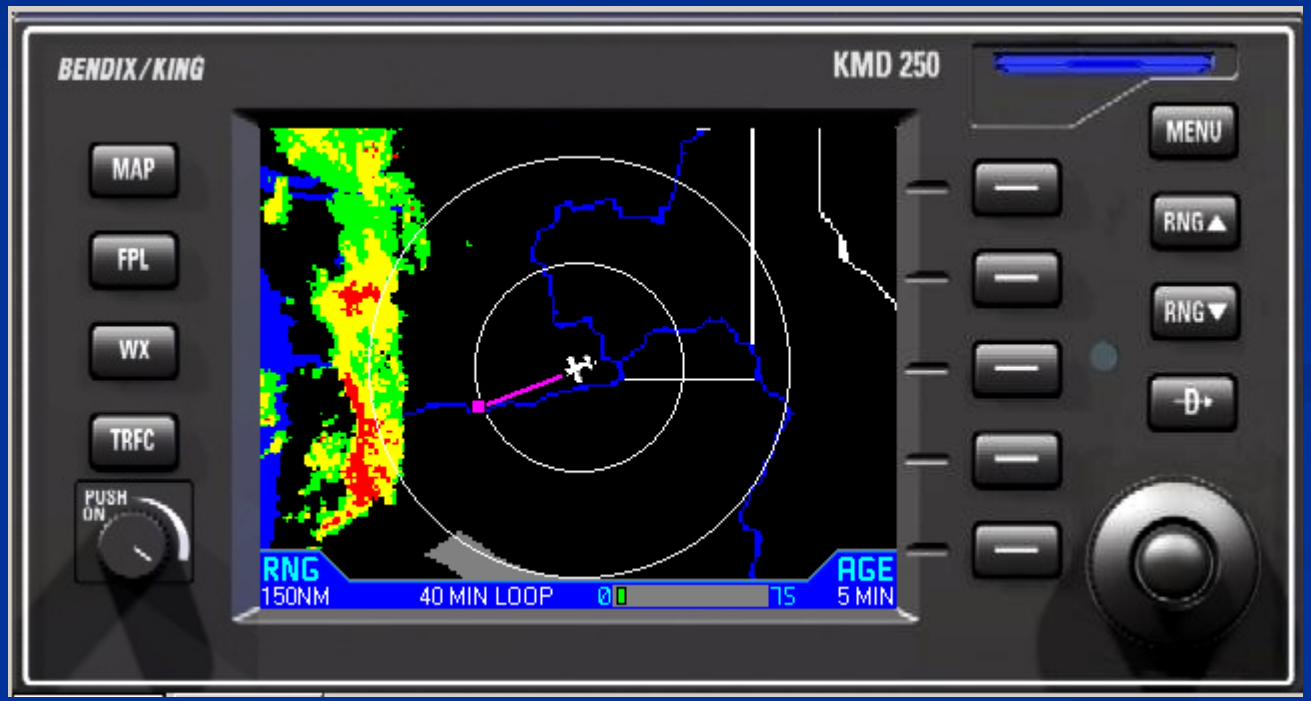
Loop Elapsed Time

Loop Age

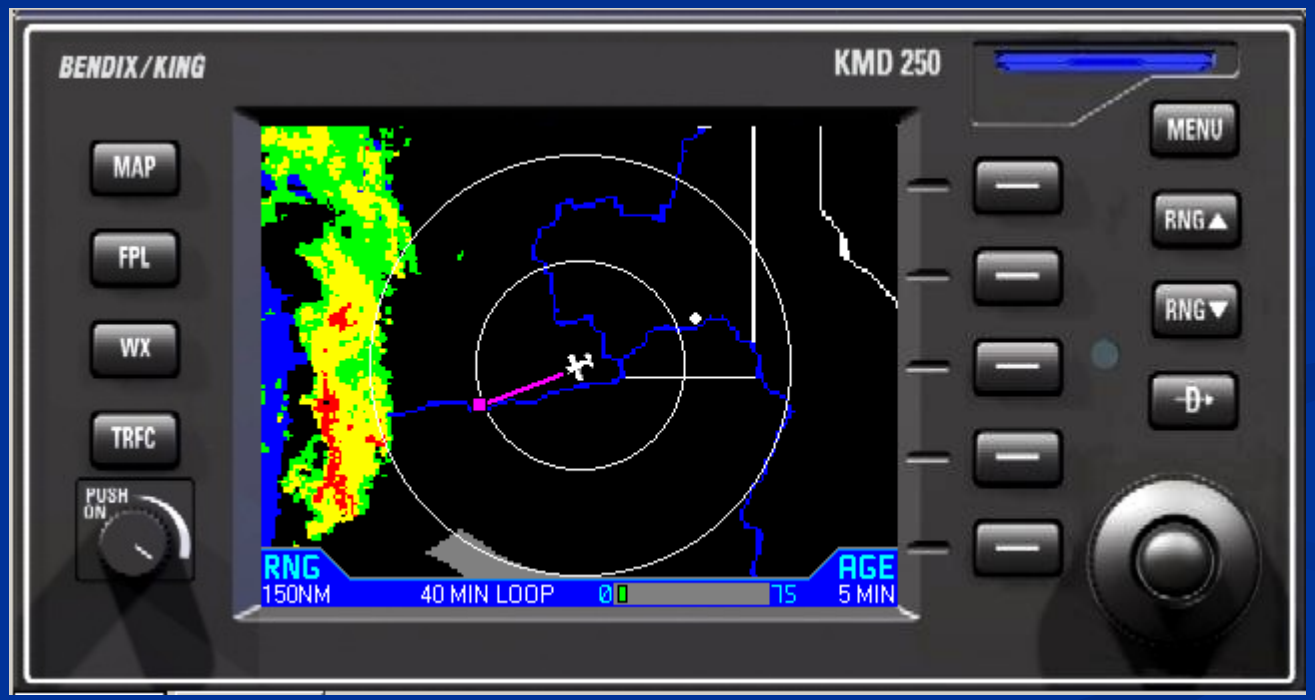
Moving Reference Frame: “Aircraft Looping” Concept

- Concept: Concurrently Depict Animated Weather and Aircraft Track History
- Implementation: Avionics Stores and Displays Matching Aircraft Prior Position On Each Weather Loop Image

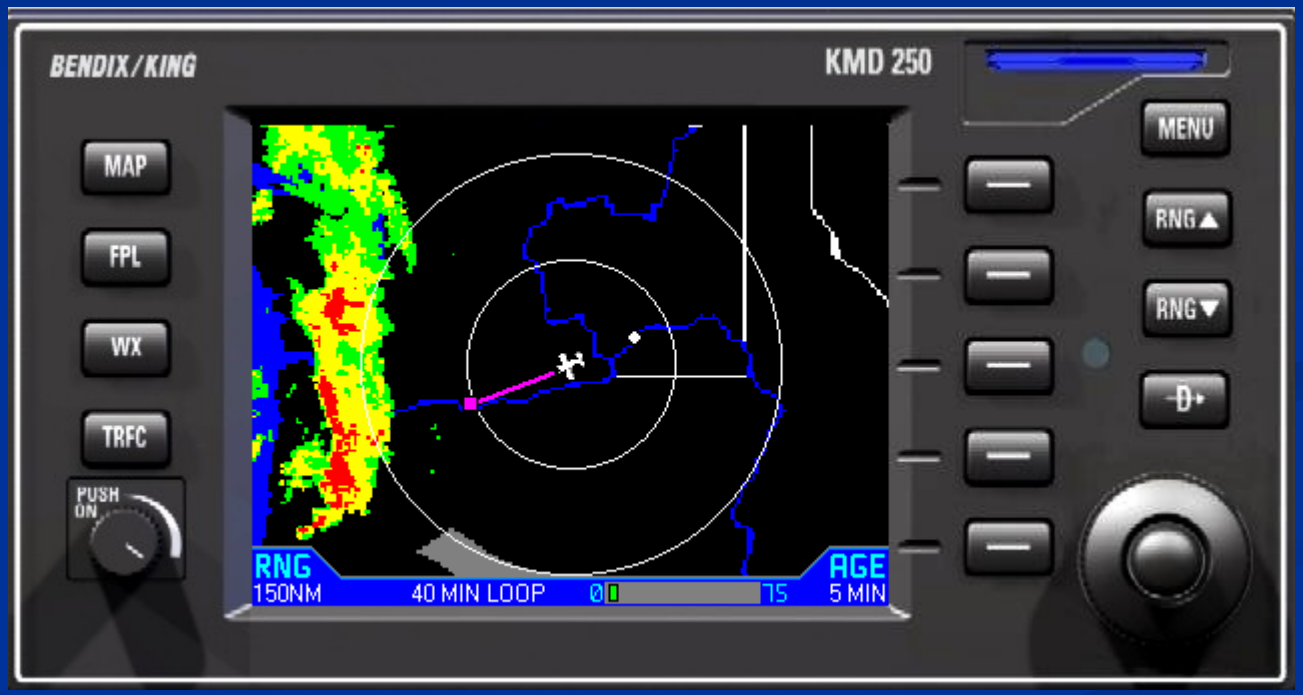
Aircraft Looping Example: Initial Static Image



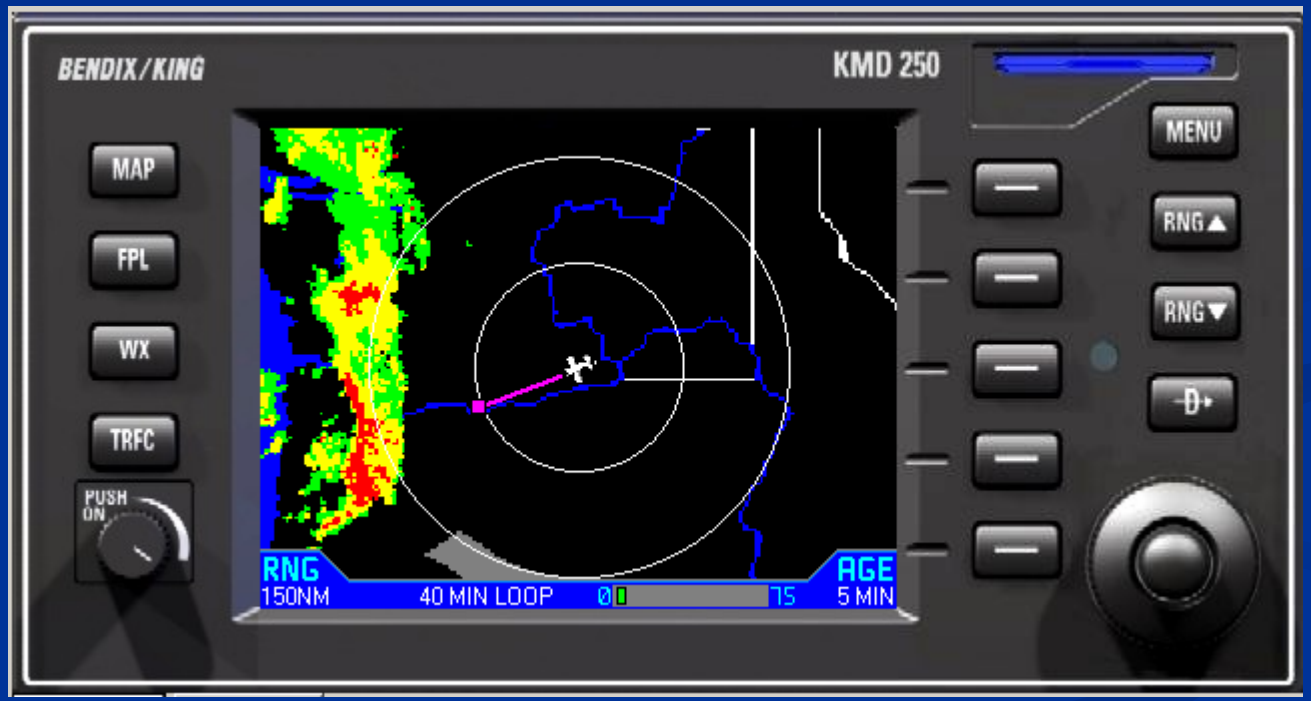
Example: 3-Frame Loop, Frame 1



Example: 3-Frame Loop, Frame 2



Example: 3-Frame Loop, Frame 3



Weather Looping: Shorter Planning Horizon When Airborne

- In-Flight is a More “Tactical” Environment Than Pre-Flight
- Shorter Loop Elapsed Times (“Time Histories”) May Be Better In Flight
  - What is optimal?

Limited Data-Link Capacity, Avionics Performance

- Fewer Loop Frames “Costs” Less
  - Assumes entire loop packaged & sent as one product
  - Fewer frames = more capacity for other products
- How Does Looping Effectiveness Degrade as Frames are Reduced?
  - What frame counts are most “cost-effective?”

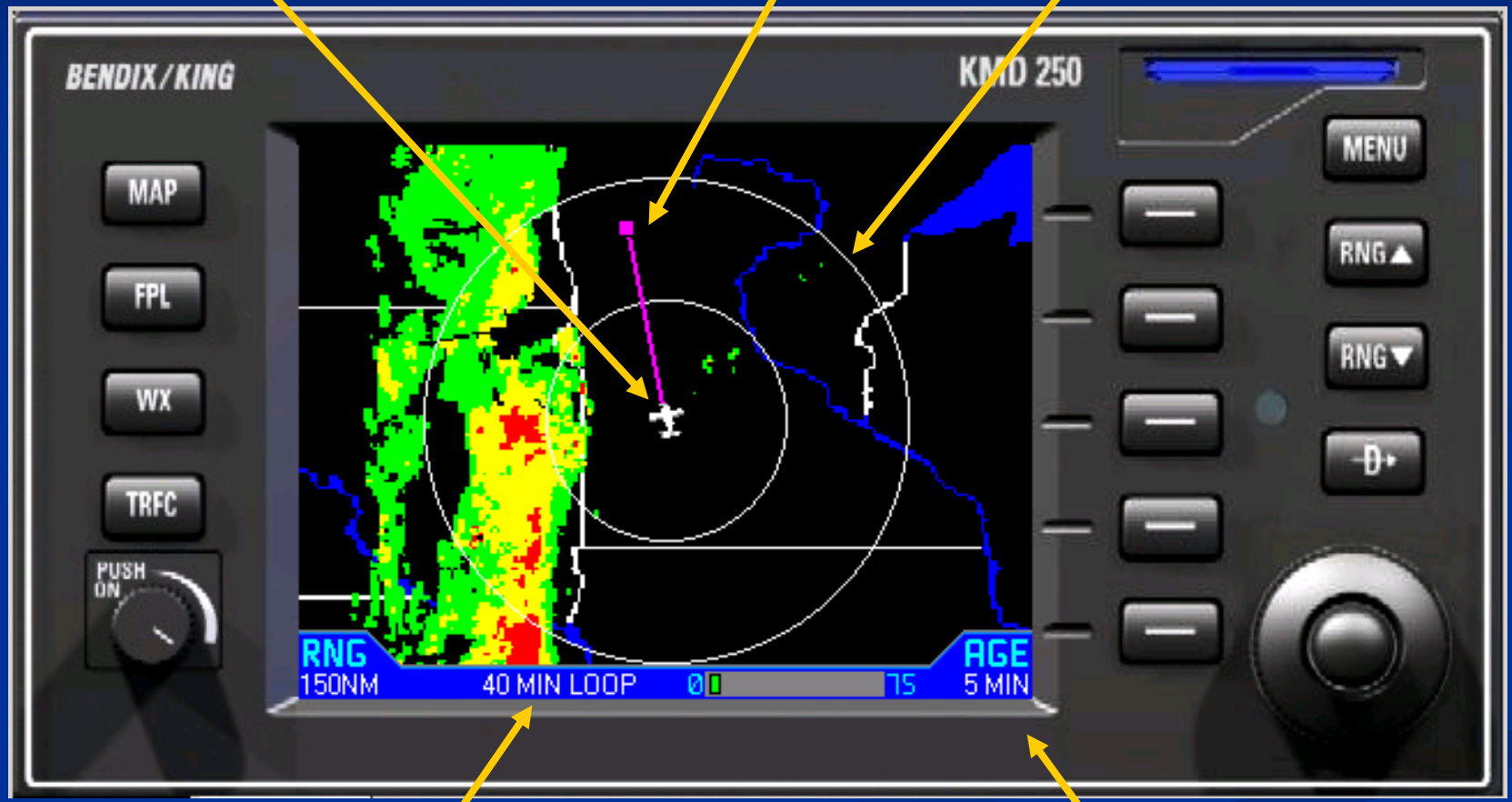
Experimental Approach

- Vary Looping Parameters, Assess Pilot Weather Awareness
- Experiment Design Challenges
  - Individual differences, sequence effects, plus…
  - Variability of weather (additional random variable)
  - Large domain of looping parameters
- Experiment Design Approach
  - Show many weather and looping scenarios to many pilot volunteers
  - Multiple counterbalanced, randomized presentation orders
  - Multiple experiments to keep matrix sizes manageable
  - Automate the experiment setup for cost-effectiveness

Two Looping Experiments

- Experiment 1
  - April-May 2004: LaRC, ERAU, OU
  - 65 pilots, ~14,000 data points
- Experiment 2
  - August-September 2005: LaRC, UND
  - 50 pilots, ~17,000 data points
- Both Experiments
  - Four-hour sessions, ~6 pilots/session, with laptop computers
  - Included preference/use questionnaires & debrief sessions

Example Looping Experiment Scenario


Aircraft: Current Location
Future Flight Path and Destination
Range Rings: 75nm and 150nm
BENDIX/KING
KMD 250
MAP
FPL
WX
TRFC
PUSH ON
MENU
RNG▲
RNG▼
D
RNG
150NM
40 MIN LOOP
0
75
AGE
5 MIN
Elapsed Time: 40 min
Product Age: 5 min

Exp 1: Independent Variables

- Number of Frames
  - 3, 5, or 9
- Exposure Time
  - 4.5, 9, or 13.5 seconds
- Loop Time
  - .5, 1.0, or 3.0 seconds
- Aircraft Looping
  - On or off

Current Image: 10 Sec

Loop Time: 3.0 Sec

Final Image Dwell: 1.5 Sec

Total Loop Time: 4.5 Sec

Exposure Time: 4.5 Sec

Exp 1: Dependent Variables

- **Performance Measures:**
  - Questions after each scenario:
    - Future encounter with weather (y / n)?
    - Future distance from weather (nm)?
- **Subjective Measures:**
  - Questions after each scenario:
    - Level of confidence in performance question responses
  - Pre- & post-experiment questionnaires:
    - Perceptions and pilot rankings

Summary of Performance Results: Experiment 1

- Frames
  - Best performance with 5 or 9 frames (Note: Elapsed Time fixed at 40 minutes. Strong preference for 60 minutes.)
- Loop Time
  - Trend for best performance at 1.0 or 3.0 second cycle
- Exposure Time
  - Same performance 4.5 to 13.5 seconds
- Aircraft Looping
  - Inconclusive (carry-over effects – within-subjects design)

Experiment 2 Objectives

- Generalize and Expand Experiment 1 Results
  - Vary Elapsed Time & Temporal Resolution as well as Number of Frames; determine optimal values
- Resolve Aircraft Looping Issue
  - Use between-subjects design to eliminate carry-over effects

Elapsed Time, Temporal Resolution, & Number of Frames

- Elapsed Time, Temporal Resolution, & Number of Frames are interdependent variables

- Increasing the Number of Frames:
  - Increases the viewer's "sense of animation"

  and

  - Yields a finer Temporal Resolution, if Elapsed Time is fixed

    or

  - Yields a longer Elapsed Time, if Temporal Resolution is fixed

Elapsed Time, Temporal Resolution, & Number of Frames

Temporal Resolution (minutes)

Elapsed Time (minutes)	5	10	15	20	30
30					
40	9	5		3	
60					
90					
120					

Cells show Number of Frames (Experiment 1)

Elapsed Time, Temporal Resolution, & Number of Frames

Temporal Resolution (minutes)

Elapsed Time (minutes)	5	10	15	20	30
30		4	3		2
40	9	5		3	
60		7	5	4	3
90		10	7		4
120		13	9	7	5

Cells show Number of Frames (Experiment 1 & 2)

What We *Think* Now

- Performance & confidence higher, workload lower with aircraft looping
- Best performance with 60-minute Elapsed Time; next-best with 30 minutes
- Best performance with 10-minute Temporal Resolution
- Best “performance per frame” with shorter Elapsed Times (60 or 30) and fewer frames (4 or 5)

What's Next?

- Complete & Document Experiments 1 and 2
  - Results will provide looping product design guidance
- Consider Other Moving-Reference-Frame Cues
  - Track history lines
  - Projection lines, arcs
- Add a "Flying" Workload
- How "Tactical" Can We Go?
  - Can animation ameliorate product age effects?
  - Compare with the tactical avoidance "gold standard" – onboard weather radar

Questions?